Snowmass TDAQ Subgroup: Introduction

Darin Acosta (Florida), Wes Ketchum (FNAL), and Stephanie Majewski (Oregon)

Today’s Meeting

- Introduce ourselves and some info on the Snowmass process
- Outline a few key TDAQ challenges to prompt thoughts and ideas
- Hear from you!
  - Many short prepared presentations: *please try to be brief*
  - A hello and introduction from anyone else present!
- Discuss some plans and ideas for this group moving forward

Who we are

- Darin Acosta
  - University of Florida, Department of Physics
  - CMS experiment, Level-1 muon trigger, incoming Trigger co-coordinator
- Wes Ketchum
  - Fermilab, Scientific Computing Division
  - MicroBooNE, SBN, and DUNE experiments, LArTPC DAQ and *artdaq* framework
- Stephanie Majewski
  - University of Oregon, Department of Physics
  - ATLAS experiment, LAr calorimeter trigger electronics

The Snowmass Process

- Community-driven effort on long-term planning for particle physics
  - See APS Town Hall from Young-Kee Kim: http://meetings.aps.org/Meeting/APR20/Session/D23

- Instrumentation Frontier focus on detector technologies and R&D needs for future experiments across the physics frontiers

- Milestones along the way:
  - **Letters of Interest** due 31 Aug 2020
  - (Virtual) Community planning meeting: 4-6 Nov 2020
  - Summer Study meeting meeting: 11-20 July 2021
  - **Contributed Papers** due July 31 2021

“Letters of Interest” and “Contributed Papers”

- **Letters of Interest (LOI)**
  (submission period: April 1, 2020 – August 31, 2020)

“They allow Snowmass conveners to see what proposals to expect and to encourage the community to begin studying them. They will help conveners to prepare the Snowmass Planning Meeting that will take place on November 4 - 6, 2020 at Fermilab. Letters should give brief descriptions of the proposal and cite the relevant papers to study. Instructions for submitting letters are available at https://snowmass21.org/loi.

Authors of the letters are encouraged to submit a full write-up for their work as a contributed paper.”

- ➔ Very brief (two pages).
- ➔ Uploaded by Authors through Snowmass 2021 Wiki.
- ➔ Index of submitted LOI available on the Snowmass 2021 Wiki.
- ➔ Could represent existing work (cite) or new ideas.
- ➔ Will help the IF conveners plan the work of the Frontier (including liaisons with other Frontiers: avoid duplication/build synergy).
- ➔ If further developed in the context of the Snowmass 2021 exercise could lead to a Contributed Paper.

See IF Introduction talk,
https://indico.fnal.gov/event/43730/

“Letters of Interest” and “Contributed Papers”

- **Contributed Papers**

(submission period: April 1, 2020 – July 31, 2021)

“Contributed papers will be part of the Snowmass proceedings. They may include white papers on specific scientific areas, technical articles presenting new results on relevant physics topics, and reasoned expressions of physics priorities, including those related to community involvement. These papers and discussions throughout the Snowmass process will help shape the long-term strategy of particle physics in the U.S. Contributed papers will remain part of the permanent record of Snowmass 2021. Instructions for submitting contributed papers are available at https://snowmass21.org/submissions/”

- ➔ More extensive studies.
- ➔ May include white papers, scientific/technical articles, etc.
- ➔ Can but do not have to be related to a given LOI.
- ➔ Submitted by Authors following instructions given on Snowmass 2021 Wiki page (submit to arXiv, send email to M. Peskin with subject “Contribution to Snowmass 2021”, etc.)
- ➔ Will be part of the official Snowmass 2021 records.

See IF Introduction talk,
https://indico.fnal.gov/event/43730/

Instrumentation Frontier Liaisons

Liaisons

Other Frontier	Liaisons
Energy Frontier	Maksym Titov (CEA SACLAY), Caterina Vernieri (SLAC)
Neutrino Physics Frontier	Mayly Sanchez (ISU), NF10
Rare Processes and Precision	Marina Artuso (Syracuse)
Cosmic Frontier	Kent Irwin (SLAC), Hugh Lippincott (UCSB)
Accelerator Frontier	Andy White (UTA)
Computational Frontier	Darin Acosta (Florida)
Underground Facilities	Eric Dahl (Northwestern), Maurice Garcia-Sciveres (LBNL)
Community Engagement	Farah Fahim (FNAL)

- TDAQ Early Career Liaisons: Brendan Regnery, George Lakovidis

Communication

- We've been working on engaging TDAQ enthusiasts across HEP
  - We need your help! Please don't hesitate to spread the word or encourage us to contact others: hopefully these slides are a good intro to share!

- Subscribe to our email list: SNOWMASS-IF-04-TDAQ@FNAL.GOV
- Slack channel: #if04-tdaq
- Wiki page: https://snowmass21.org/instrumentation/trigger
  - (which we will attempt to keep updated with important info...)

- Please see pledge to replace 'Master / Slave' terminology: https://sites.google.com/view/mspledge

Some previous collection of discussion

- European Strategy Physics Book (see Secs. 11.1 and 11.2): https://cds.cern.ch/record/2691414/files/Briefing_Book_Final.pdf

- CPAD 2018 Report (see Secs. 4.7, 4.10.5-7): https://arxiv.org/pdf/1908.00194.pdf
  - 2017 CPAD DAQ Workshop: https://indico.fnal.gov/event/14744/

- TDAQ Community Meeting for DOE Basic Research Needs (2019): https://agenda.hep.wisc.edu/event/1430/
- HEPAP Presentation on BRN (2020) linked here: https://science.osti.gov/hep/hepap/Meetings/202007
  - Darin and Wes served on the BRN Panel for TDAQ, so that forms a large basis of our overview

TDAQ Challenges

Next generation of detectors places many challenges on Trigger and DAQ

- Large data throughput
- High reliability and performance in extreme environments
- Fast timing and precise synchronization, even across large distances

We should consider advances on many possible lines

- Novel improvements on existing technologies and techniques
- Exploring and advancing emerging technologies
- Integration of TDAQ requirements, capabilities, and possibilities, into R&D efforts across instrumentation frontier and future detector design

Some specific TDAQ topics of interest (1)

- Future experiments are growing in scale, and will generate data at 100s of TB/s in challenging environments
  - E.g. high radiation, magnetic fields, cold temperatures, severe limitations on space and power

- High-speed data links for future detectors
  - Improved rad-hard optical links, photonics-based links, and wireless readout among possible solutions, but all need R&D
- Real-time on-detector processing hardware
  - Low-power ADCs ready to meet demands of faster sampling and high resolution need orders of magnitude improvement
  - Need localized data reduction, processing, and aggregation: e.g. FPGAs and ASICs for ‘low-level’ compression/zero suppression and ‘high-level’ clustering and pattern-finding
  - Incorporating precise timing into readout and triggering for handle pileup, improved particle ID

Some specific TDAQ topics of interest (2)

- Needs for high-level triggering and monitoring of detectors are increasing with detector size and event complexity, requiring advanced computing

- Online processing and improved high-level trigger algorithms
  - Development of online and real-time algorithms that can make further use of heterogeneous computing (CPU, GPU, FPGA, etc.), and tools to make that possible (e.g. HLS)
  - Includes artificial intelligence/machine learning/neuromorphic computing algorithms and fast inference
- Autonomous systems for operation, calibration, and control
  - Anomaly detection, fault recovery, and automated calibration for detector stability and efficient DAQ will be critical for complex detectors and high uptime demands
  - Prime place to take advantage of AI/ML techniques to automate feedback

Some specific TDAQ topics of interest (3)

- Architecture of DAQ systems is evolving with needs of large detectors and improvements in readout electronics and computing

- Precision synchronization
  - Precise timing creates need for ~picosecond synchronization of detector components for event/interaction disambiguation, phase coherence, and absolute time comparisons at km and greater scales
- Solutions for system-level architecture improvements in DAQ
  - “Streaming” and asynchronous readout components allow for more R&D in shared readout techniques and technologies (e.g. “computing-as-a-service” with well-defined latencies for high-level event filtering)

Some specific TDAQ topics of interest (4)

- And of course, your further ideas here!

Future TDAQ Subgroup Planned Activities

- Have dedicated discussion at the end of this meeting, time permitting
- Want activities of this group to be community-driven and useful
- Thinking to have a dedicated TDAQ virtual workshop in early August
  - Thinking August 6 to get in before LOI deadline
    - (but there is a conflict with last day of ICHEP)
  - Solicit brief presentations of LOI ideas to encourage further feedback and collaboration
  - Organize session(s) for broader discussion of needs in TDAQ
    - Particularly “what’s missing” from the presented ideas and plans
- After that … your ideas welcome!

Backup

Some specific thrusts

- High-speed data links and transfers
- Real-time processing hardware
  - Heterogeneous (ASIC, FPGA, GPU, CPU)
- Architecture (triggered vs. streaming, synchronous vs. asynchronous, how our computing is distributed ‘computing as a service’)
- Online processing and improved high-level trigger algorithms
- Autonomous systems for operation, control, and calibration
- Precision timing for improved triggering and synchronization
- Make sure to get the difference in needs for different frontiers (high energy, neutrino, intensity, cosmic)

Key overlap/shared concerns with other (sub)groups

- TDAQ necessarily takes as input the requirements of the detectors
  - Electronics/ASICs a key integration point, but systems-level understanding critical for making an experiment work

- TDAQ not only makes use of advancements in computing, but is a key driver for what the needs of offline computing are
  - Parallelized algorithms and machine learning critical to future online triggering algorithms
  - Balance the abilities of TDAQ with the abilities for offline computing, networking, and storage to keep up

- Of course, connections to all groups/frontiers critical for building the detectors, facilities, and communities to achieve our physics goals